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merable fish were captured with salt bait, or the viscera from the catch of the day before? This fact illustrates a most striking characteristic of the American fisherman—the strong conviction that the fish have decided preferences in the matter of bait and will not take any kind which is out of season. He will often spend the entire month of August in fruitless search rather than use herring or capelin and gain but a moderate success; nor could any argument convince him that a codfish would bite at a salt clam while "the fleet was using squid."

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THE BRAIN OF THE EMBRYO AND YOUNG LOCUST.[1]

BY A. S. PACKARD, JR.

[*Continued from April number.*]

Structure of the Brain in the Embryo Locust.—Much light may be thrown upon the structure of different parts of the adult brain if we can trace their origin in the embryo, or in the larval and pupal conditions. Hence, we have, with what material we could obtain, made a series of sections of the embryo and different stages of the larva and pupa, with some results of considerable interest and importance. No one, we belive, has yet examined the topography of the brain of the embryo insect. The only observer who has studied the brain of the larva, as compared with the adult, has been Flögel. Speaking of the cockroach, he says:

> "Of special interest would be an investigation of the development of the separate parts of the brain. The difficulty of making preparations of small heads has been such that no particular results have been reached. Still, I can say this much, that in small creatures, 7–8 mm. in length, all the parts are present, only of a finer and more delicate structure than in the large adult 25 mm. in length."

He says that in the Hymenoptera he has discovered much concerning the development of the parts of the brain; that in bee larvæ the calices are present, though very small and with thin walls. The peduncle and trabecula have reached their ultimate proportions more nearly than the cauliculus, which is still very thin. In the larval ants the central body and entire mushroom

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[1] Adapted from the 2d Report of the U. S. Entomological Commission, Washington, 1880.

Plate IV.

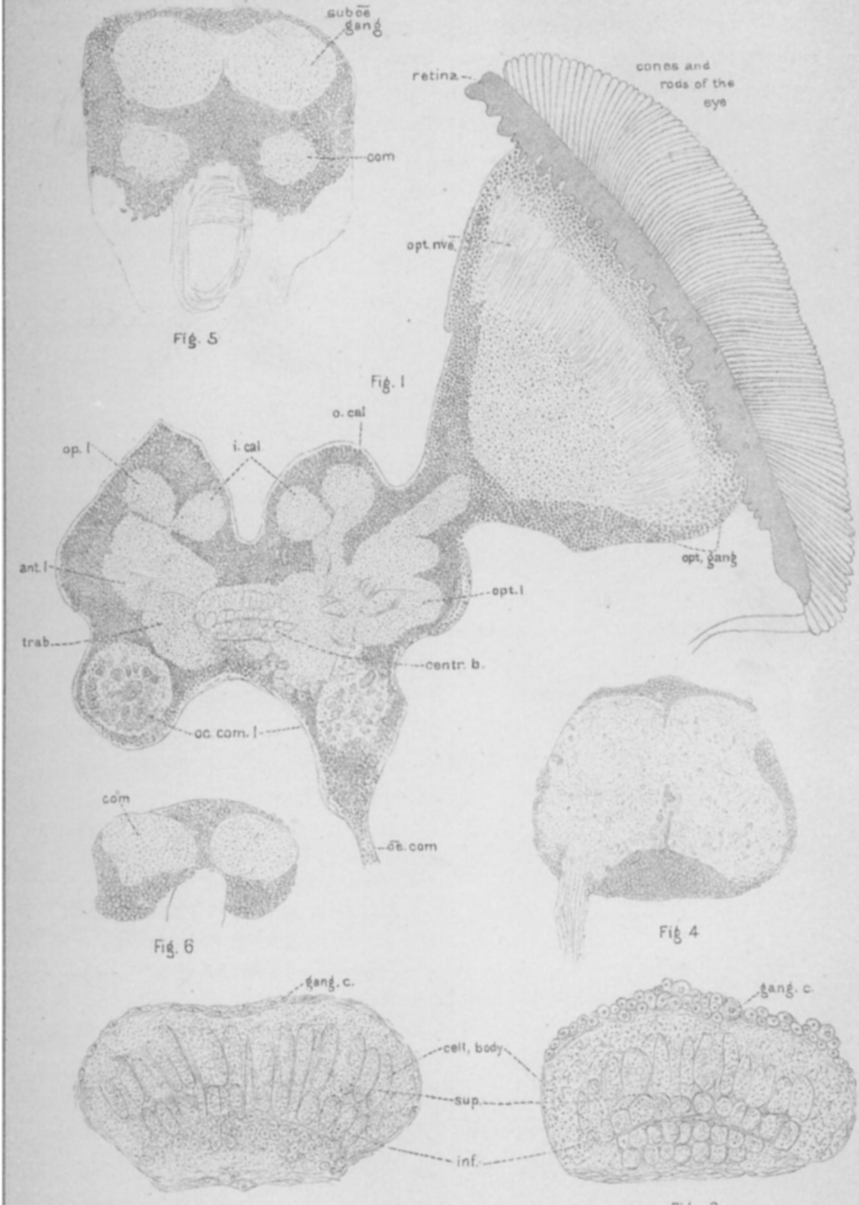

Fig. 5

Fig. 1

Fig. 6

Fig. 4

Fig. 2

Fig. 3

A. S. Packard, del.

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bodies are present, though an early larval stage shows, in place of the calices, four symmetrically situated balls of much smaller size; the central body was very flat, and the other parts were wanting. In the pupa all the parts had attained their definite shape. It appears from his observations that the calices are the last to be developed.

He then gives the results of his examination of the brain of caterpillars, as compared with that of the adult sphinx moth. In a caterpillar examined near the time of pupation, the central body is very much undeveloped, forming a small linear transverse body (Querleiste), while the different parts of the mushroom body are indicated. In smaller caterpillars it is scarcely possible to work out the development of the brain. In that of *Pontia brassicæ* the mushroom body and central body were undeveloped, while in that of an Euprepia larva the double stalk of the mushroom body was developed, as well as roundish calyx masses. But in a Noctuid larva the entire mushroom body, including well-developed trabeculæ and a very flat central body, was present.

The brain of the mature pupæ of Lepidoptera, for example *Saturnia carpini*, contains all the portions of the adult brain, and in the same relative proportions. But a brain of *Sphinx ligustri*, in a considerably younger stage of development, did not differ much from the brain of the larva.

We offer the following observations on the brain of the embryo locust, shortly before hatching, with much diffidence, as we are liable to be corrected by future observations in the same directions. The embryos were taken from the egg-shell, hardened in the usual manner, and then cut by Mr. Mason, the sections being frontal, the entire insect being embedded in a mixture of paraffine, wax and oil.

In the youngest stage (which we will call stage A) observed, the body and appendages were formed and the eyes with their facets, the pigment mass coloring the cornea pale reddish.[1]

At this stage, as seen in section 7, the antennal and optic lobes of the brain are indicated, but the central body and mushroom bodies are not yet differentiated. In a plane lying in front of the optic and antennal lobes, the brain is divided in each hemisphere into two regions or lobes, *i. e.*, an upper and lower cerebral lobe. From these embryonic cerebral lobes, are eventually developed the central body and the two mushroom bodies. The stratum of cortical ganglionic cells is, at this period, quite distinct from the paler unstained granular brain matter. The ganglionic cell-portion gradually passes into the central white brain substance, which is composed of fine granules or nuclei alone, and which do not apparently differ from the granules scattered among the ganglion cells. It is to be observed that there are no fibers among the granules. It thus appears that the brain of insects, like the other ganglia, originally consists of a paler portion formed of fine clear granules (nuclei ?), enveloped by a thick, irregular layer of nucleated cells, containing fine granules outside of the nucleus.

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[1] Compare the 2d Report of the U. S. Entomological Commission, Pls. XII, XIII.

As the fibers of the adult brain are evidently secondary products, it would appear that they must be transformed granules or nuclei, and not in all cases, at least, the fibers thrown off from the ganglion cells, although at this time the ganglion cells have no fibers, the fibers of those seen in the adult brain being also secondary growths. It may be that the white inner granulo-fibrous matter of the adult brain is (1) made up of modified granules, which in some cases remain such, and in others form fibers, and (2) of fibers sent in from the cortical ganglion cells.

Comparison of the Brain at this Stage with the first Thoracic Ganglion.—If we compare at this stage of development of the nervous system the brain with one of the ganglia of the trunk, we shall obtain a fair idea of the primitive difference between the brain and one of the ordinary ganglia. By a glance at the figures of the two it will be seen that the organization of the thoracic ganglion is essentially simple. It is divided into two portions or regions. The central granular region is enveloped by a thick stratum of cortical ganglion cells. The whole ganglion in section is rudely hour-glass-shaped and much smaller than the brain. There is no differentiation into distinct lobes as in the brain. The formation of the brain, as is well known by embryologists, is one of the earliest steps in the development of the nervous system, the entire system being at an early date in the life of the embryo set apart from the epidermis or integument, the latter with the nervous system originating from the ectoderm or outer germ-layer.

Second Embryonic Stage, B.—In embryos more advanced, and just ready to hatch, the eyes being now dark red, the central body is formed, but our sections do not show any traces of a mushroom body. The sections are frontal, and we will describe them in order. The fifth section is through the head and front part of the eyes, but does not graze the brain itself.

Section 6 passes through the outer portion of the optic and antennal lobes, now clearly differentiated.

In section 7 the cerebral lobes are seen, and in section 8 are larger, as are the optic lobes, while the antennal lobes are somewhat reduced in size. Section 10 passes through the cerebral lobes and also grazes the optic lobes, passing through the optic ganglion.

Section 11 shows the central body, separated from the upper cerebral lobes by a thin layer of loose ganglionic cells. The relation of the central body to the upper and lower cerebral lobes is well shown in this section.

Section 12 passes through the lower cerebral lobes and the upper left cerebral lobe and the optic ganglion. The œsophagus is situated beneath the cleft under the lower cerebral lobes. The next section (13) passes behind the brain, not touching it. These sections are $\frac{1}{500}$ inch thick.

Structure of the Subœsophageal Ganglion.—In its form this nerve center is more like the brain than the first thoracic ganglion. The figure is drawn from the youngest embryo observed. The ganglion seen in section is very much larger and quite different in shape from the thoracic ganglia. It expands above the lower fissure between the two sides, being very deep and narrow, while the superior furrow is broad and shallow. The internal paler portion (when magnified 400 diameters) is seen to consist of granules. The stratum of outer cells (the future ganglion cells) is thickest on the outside of the upper part of the ganglion, and at the base of each hemisphere.

The Brain of the freshly-hatched Larva of C. spretus.—In the larva but a few hours after hatching, the brain, so far as I can learn from four sections, does not essentially differ from that of the embryo just before hatching, as the interval is apparently too short for a decided change to take place. It is evident that by the end of the first larval stage the brain attains the development seen in the third larval state of the two-banded Caloptenus.

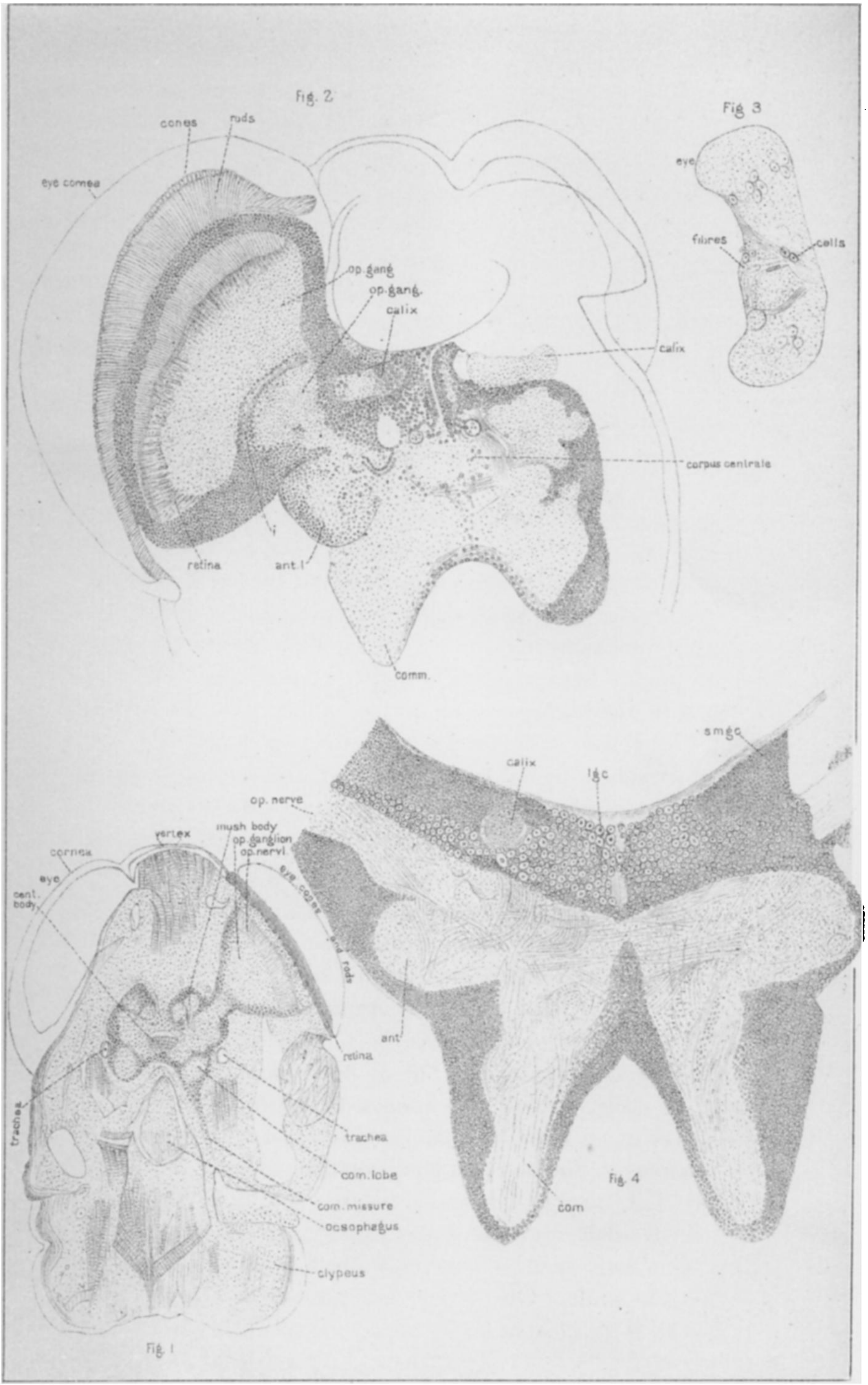
For illustrations of the different larval and pupal stages of development of the locust, the reader is referred to the first Report of the Commission (Plates I, II, III).

Third Larval Stage of Caloptenus bivittatus.—In the third larval condition of another species, the common *Caloptenus bivittatus* of our gardens, the different parts of the brain have attained nearly the same structure and proportions as in the adult. Pl. xiii, Fig. 1, of the second report represents a section passing through the front of the brain, and also the lateral ocelli and the right eye. The ganglion cells surrounding and filling the calices are smaller and more crowded than elsewhere. The mushroom bodies are now formed, though the trabeculæ are not to be seen in our section, but the entire double stalk and calices are very clearly seen. The fibers from the stalk are observed to extend along the inner edge of each calyx and to suddenly stop just beyond the middle. The granular calices contain slight irregularities and sinuous lines, as shown in Fig. 2, *i. cal.*, *o ca.*, but to what these appearances are due it is difficult to say; there are also a few scattered large granules. As the section passes through the front of the brain, where the hemispheres are separated by the frontal furrow, the lobes are not well marked, but the substance is made up of irregular intercrossing bundles of fibers, with the interspaces filled with granulated matter. In Fig. 3 the regular saucer-like form of the calyx is well shown. Fig. 2 is an enlarged view of the right side of Fig. 1, and at this stage large important bundles of fibers are seen passing into the optic, antennal, and commissural lobes.

First Pupal Stage of Caloptenus spretus.—My sections are too imperfect to describe, but the form of the brain is closely like that of the next stage.

Second or last Pupal Stage of Caloptenus spretus.—A number (14) of very successful sections, made by Mr. Mason from one head, give an excellent opportunity for studying the head of the locust in this stage, just before becoming fledged (see first Report, Pl. i, Fig. 5). Of these sections, Nos. 8 and 9 pass through the calices and œsophageal lobes, but do not reach the central body. Section 10 (Fig. 1, of Pl. iv) passes through the central body, which is $\frac{1}{500}$ of an inch in thickness, the section itself being of the same thickness. In the optic ganglion the section passes through the front of it, but two lenticular masses appear. The trabeculæ are as in the adult, and the superior and inferior intra-trabecular nerves are clearly seen to pass into the center of each trabecula just as in the adult. On the left side the origin of the cauliculus and peduncle is clearly seen, under a power of 225 and of 400

Plate V.



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diameters, the relation of parts being exactly as in the adult (see Pl. II, Fig. 3). The base of the two divisions of the double stalk arise suddenly, as if inserted into or resting simply upon, rather than arising from, the trabeculæ; the bases of the cauliculus and peduncle being in the same line with the base of the center of the upper division of the central body. It appears as if a few nerve fibers passed under the base of the stalk between it and the trabecula; at any rate, I have been unable to observe either in the pupa, or larva, or adult among a number of preparations, any continuity between the trabeculæ and the double stalk.

In this section the curving of the double stalk backwards and the passage in front of this double column is to be clearly seen, and is just as we have described it from similar sections of the adult brain (Fig. 3 of Pl. II). The ball-like masses in the œsophageal commissures are as distinctly shown as in the adult.

Section 11 passes behind the central body, not showing it nor the basal part of the double stalk of the mushroom body. This section, and those behind it, show well the structure of the optic ganglion. In section 11 the three lenticular bodies clearly appear.

The main, and almost the only difference between the second pupa and the adult appears to be in the degree of development of the central body. In the second pupa (Pl. IV, Fig. 3) it is rather more elementary than in the adult, the upper and lower series of unicellular bodies being a little shorter and rounder, nearer their primitive condition, and the septa between them are plainly fibrous. Their contents are as finely granular as the adjoining parts of the body.

Section 11 is instructive as showing a bundle of directly ascending and obliquely ascending fibers from the back part of the trabecula, of which a portion is contained in the section. Two large bundles enter the commissural lobes, one from above and one from the inner side under the central body, the bundle from above passing down into the lobe from around the upper side of the trabecula. From this fact we should infer that there is a partial nervous communication between the trabeculæ and the commissural lobes. The fibers enveloping the trabecula above are more numerous, the mass of fibers much thicker than in section 10, showing that what we supposed to be fibers separating the stalk from the trabecula appear to be really such.

A broad bundle of fibers is also seen on the right side, passing down from the upper side inside of the upper end of the peduncle, down outside and back of the central body, and is seen to enter the commissural lobe on its inner side, terminating at the point where the ascending fibers to the upper side of the trabecula originate. There is thus a direct communication between the upper part of the brain and the œsophageal commissure in the lower part. It appears, also, that three large nerves or bundles of fibers enter each commissural lobe from above.

At the under side of the commissural lobes the cortical ganglion cells (some of them very large) appear to send their fibers into others to build up the mass of fibers enveloping the lobe. Flögel states that the opinion that the ganglionic cells in winged insects are in direct relation through the fibers with the organs of the body are unfortunately provisionally contradicted by his observations. But here (seen in a portion of the commissural lobe not represented in Fig. 3 of Pl. III), as in one or two other places, we think we have seen fibers from the cortical ganglion cells passing into and aiding in building up the nerves. Such a relation is very plain in the brain of the horseshoe crab, *Limulus polyphemus*.

EXPLANATION OF PLATE IV.

FIG. 1.—Enlarged view of brain and eye of *C. spretus* in the second pupal stage; × ½ A. This view of the brain is taken from the same preparation (No. 10) as Fig. 1, Plate V. *Centr. b.*, the central body, showing the two series of cells in the lower division and the two rows of unicellular bodies in the superior division; *œ. com. l.*, œsophageal commissural lobes, with the ball-like masses distinctly seen, though this preparation was stained only with picrocarmine; *œ. com.*, œsophageal commissure; *opt. nvl.*, optic nervules; *retina*, retina with rods and cones beyond, the cornea not shown.

FIG. 2.—The central body of adult *C. spretus*, from section 17, showing the inferior and superior divisions, the cells in inferior division (*inf.*), and the two rows of unicellular bodies (*ce. cell. b.*) in the superior division (*sup.*). Magnified 225 diameters.

FIG. 3.—The central body of the second or last pupal state, from section No. 10; *c*, cells in the fibrous septum between the lower and upper divisions of the central body, from section No. 11. × 225 diameters.

FIG. 4.—Vertical section of the subœsophageal ganglion of the cockroach (*Blatta orientalis*), showing the commissure on the left side.

FIG. 5.—A section farther behind, showing the back of the ganglion (*gang.*) of the cockroach, seen separate from the commissure (*com.*).

FIG. 6.—A section through the commissure just behind the ganglion of the cockroach.

EXPLANATION OF PLATE V.

FIG. 1.—Frontal section No. 10, through the head of second or last pupal stage of *C. spretus*, passing through the middle of the brain, the optic ganglion and eyes,

and cutting across the œsophagus. Drawn in order to show the relation of the brain to the eyes and the exterior of the head; magnified 30 diameters. In the brain, the right mushroom body is seen, while the optic and antennal lobes are not so well marked. The central body (*centr. b.*) is cut through near the middle; below are the trabeculæ (*trab.*); next to the commissural lobes, two tracheæ (*tr.*) or air-tubes passing near the brain. The commissure to the subœsophageal ganglion is drawn on the right side, passing down the œsophagus. In the eye, the cornea, the respective portions composed of rods and cones, the black retina, the stratum of optic nervules, and the optic ganglion and optic nerve passing off from the optic lobe, are all well marked.

FIG. 2.—Section through the brain and eyes of the same second pupa of *C. spretus*, passing through the anterior part of the calices, but not through the central body. The section is oblique and does not well represent the right side.

FIG. 3.—Calyx of the section represented by Fig. 2; magnified 225 diameters. It is composed of granulated nerve substance with a few fibers, the continuation of those of the stalk, and with a few ganglion cells.

FIG. 4—Section through the back of brain of the adult *Locusta carolina*, passing behind the mushroom body, showing the œsophageal commissures, the antennal lobes, and the bundle of nerve-fibers crossing to the right hemisphere. The left calyx is cut through, the microtome-razor passing behind and not grazing the right mushroom body. The distribution of the large (*l.g.c.*) and small ganglion cells (*sm. g. c.*) is well seen in this section. It will be seen that the brain of *Locusta carolina* does not differ in any respect from that of *Caloptenus spretus*, so far as the sections show.

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EDITORS' TABLE.

EDITORS: A. S. PACKARD, JR., AND E. D. COPE.

—— It is rumored that at the next meeting of the American Association for the Advancement of Science, to be held in Cincinnati in August of this year, a proposition will be brought forward to extend an invitation to the British Association to depart from their usual custom so far as to come over to this country in 1883, and hold their annual meeting for that year in conjunction with the American Association, at some place hereafter to be fixed upon. A number of the most prominent scientific men in the States and Dominion are known to be in favor of the plan, and doubtless the members of our Association will be glad to send such an invitation as a mark of our cordial feelings towards the students of science in the mother country. It will give us great pleasure if it should prove practicable for the English body to accept. We hope that the proposition may be happily successful. The advantages of such a gathering of scientific men from two countries having a common language, are as evident as they are great. The meetings of the American Association have proved